



Integrating Earth Observation and Satellite Telemetry of Wild Birds for Decision Support System of Avian Influenza

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This NASA Public Health project is built upon our previous projects, including NIH-funded Ecology-based risk assessment of avian influenza in Asia

NASA Land Use and Land Cover Change

National Institutes of Health

National Science Foundation

USGS

FAO

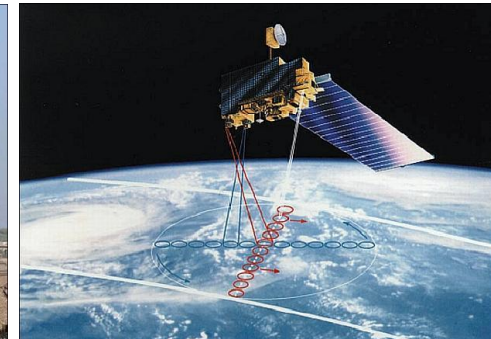
Belgium

Marius Gilbert

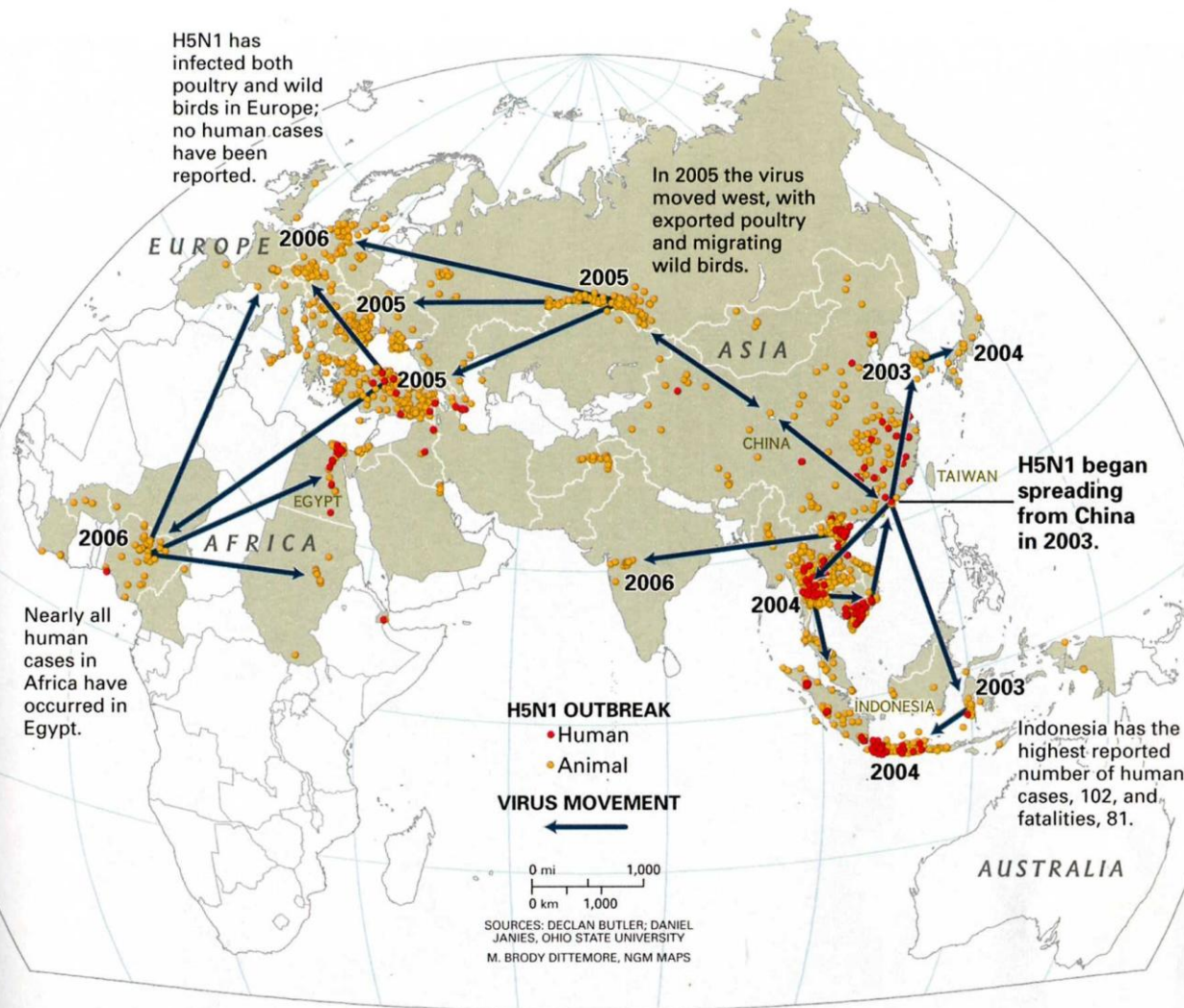
Many in-country collaborators

In China, Mongolia,

Bangladesh and India



Global patterns and dynamics of H5N1 HPAI (2003 – 2006)



H5N1 has continued to infect poultry, birds and people.

As of August 9, 2011,
A total of 564 human cases and 330 death

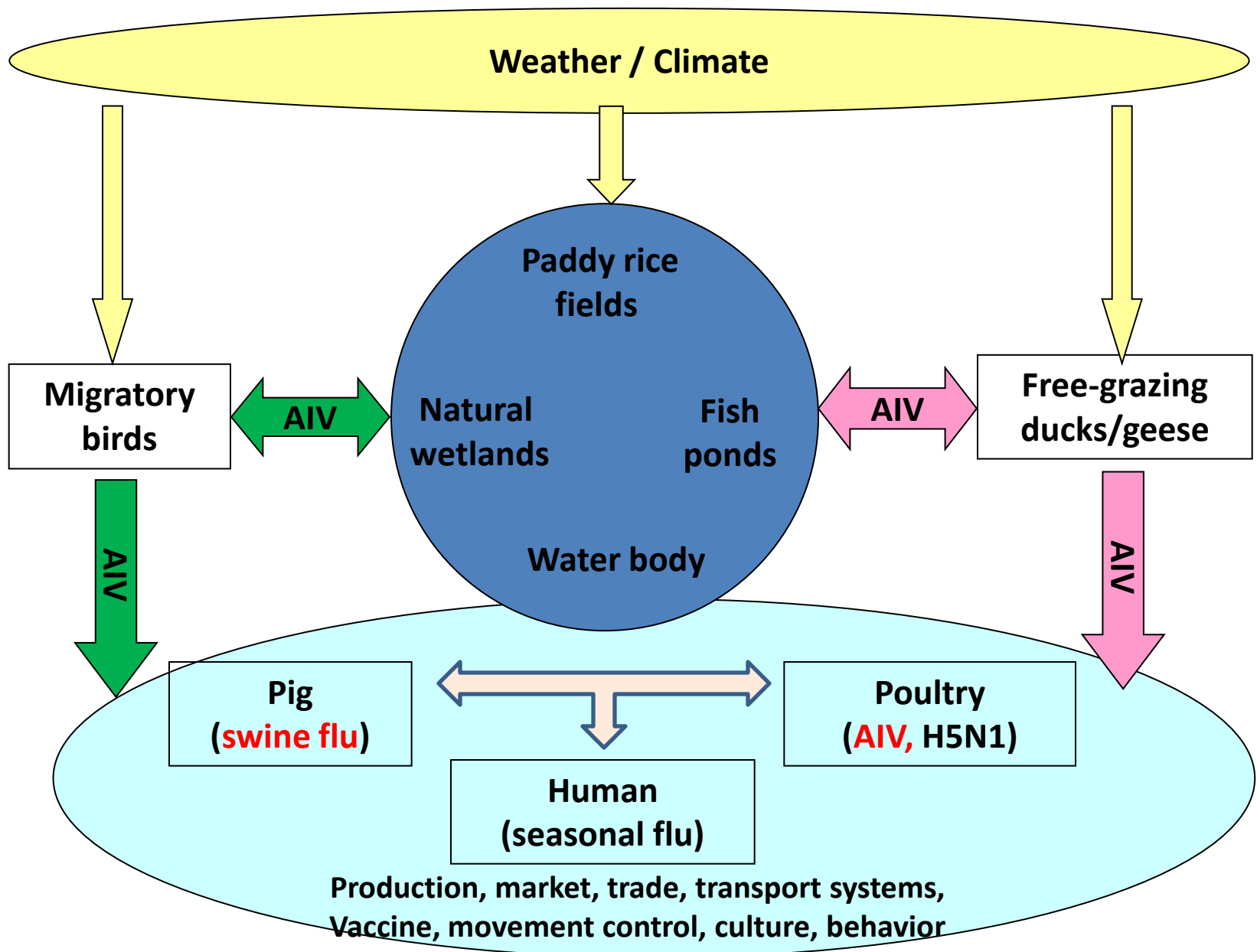
~ \$20 billion of economic damage

New H5N1 clade 2.3.2.1 in China and Vietnam in 2011

MARCH OF THE BIRD FLU The avian influenza strain H5N1 is the world's top pandemic threat. Starting in China, in 2003 it began spreading through other parts of Asia and by 2006 had shown up in Europe and Africa. Experts fear that H5N1, which has killed fewer than 200 people, may mutate to a virulent form able to wipe out millions.

From David Quammen, How animals and humans exchange disease -- Deadly Contact, National Geographic, 10/2007

Ecology and epidemiology of avian influenza



Spatial risk modeling & remote sensing

Mapping H5N1 highly pathogenic avian influenza risk in Southeast Asia

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The highly pathogenic avian influenza (HPAI) H5N1 virus that emerged in southern China in the mid-1990s has in recent years evolved into the first HPAI panzootic. In many countries where the virus was detected, the virus was successfully controlled, whereas

established, spread, and persist everywhere equally. Virus establishment is influenced by the extent of surveillance and early detection, and therefore it is subject to an unknown degree of underreporting bias. Once established, HPAI H5N1 virus spread

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PLoS PATHOGENS

Spatial Distribution and Risk Factors of Highly Pathogenic Avian Influenza (HPAI) H5N1 in China

Vincent Martin¹, Dirk U. Pfeiffer², Xiaoyan Zhou¹, Xiangming Xiao³, Diann J. Prosser^{4,5}, Fusheng Guo¹, Marius Gilbert^{6,7*}

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Abstract

Highly pathogenic avian influenza (HPAI) H5N1 was first encountered in 1996 in Guangdong province (China) and started spreading throughout Asia and the western Palearctic in 2004–2006. Compared to several other countries where the HPAI H5N1 distribution has been studied in some detail, little is known about the environmental correlates of the HPAI H5N1 distribution in China. HPAI H5N1 clinical disease outbreaks, and HPAI virus (HPAIV) H5N1 isolated from active risk-based surveillance, sampling of domestic poultry (referred to as HPAIV H5N1 surveillance positives in this manuscript) were

ZOO NOSES

In China's Backcountry, Tracking Lethal Bird Flu

Five years after flu devastated wild birds in China, researchers have confirmed one likely transmission route

QINGHAI LAKE, CHINA—The lake glitters like a sapphire under a blue sky as birds circle near the shore. On the rocky beach, two researchers are tying a GPS transmitter to the back of a small gray duck. They will track its migration by satellite, part of a series of investigations that began after highly pathogenic avian influenza (H5N1 subtype) first swept the region in 2005.

The studies aim to pinpoint the viral reservoir and the role that wild birds play in transmission. “The lake has attracted the whole world’s researchers to keep a close eye on it,” says He Yubang, vice director of Administration of Qinghai Lake Chinese National Nature Reserve. No reservoir has yet been found, but transmission routes have come into clearer focus.

The emergence of H5N1 was a disaster for wildlife and humans alike. Since 2003, H5N1 has killed 300 people, including 18 so far this year, according to the World Health Organization. More than 250 million infected domestic poultry have been culled, and thousands of wild birds have been felled. In 2005 alone, more than 6000 wild birds at Qinghai Lake died, “the single largest H5N1 wild bird mortality event that has ever occurred,” says Scott Newman, an animal health officer for the UN Food and Agriculture Organization (FAO) in Rome.

H5N1 was first isolated in 1996 from a domestic goose in China’s Guangdong Province. The next year, the virus spread to people in Hong Kong. After laying low, H5N1 flared in 2004 in several Asian nations. It kills about 60% those infected but does not spread easily from person to person. The virus has been held in check by poultry vaccination and better husbandry, but 16 countries, including China and Romania, have reported H5N1 outbreaks in poultry so far this year. A constant worry is that the virus will mutate into a more transmissible form among humans.

Because Qinghai Lake sits within the eastern portion of the Central Asian Flyway—which reaches from India and Bangladesh to Russia—some experts suspect it is a focal point of viral transmission. Others question whether wild birds play a major role in H5N1 dispersal, suggesting that the virus

spreads primarily among poultry (*Science*, 21 October 2005, p. 426). To date, all human cases but one have been associated with exposure to poultry or found on farms. Researchers now believe that wild waterfowl on the eastern portion of the Central Asian Flyway help spread H5N1 into Mongolia each spring as they move across the Qinghai-Tibetan plateau to the north and east, says Newman. The role of wild waterfowl on the other major flyway is less certain.

Poultry production is on the rise in Asia, as are farming, trade, and the mixing of wild and domestic birds. “All of them are increasing the opportunities for viral transmission and persistence,” says Xiao Xiangming, a landscape ecologist and remote sensing expert at the University of Oklahoma, Norman.

Every summer, more than 100,000 migratory birds descend on Qinghai Lake, China’s largest inland body of salt water. Half the birds that died here in 2005 were bar-headed geese (*Anser indicus*), says Lei Fu-Min, an ornithologist at the Institute of Zoology of the Chinese Academy of Sciences. Yan Baoping, chief engineer at the Computer Network Information Center in Beijing, led an academy team that set up a monitoring network after the die-off. The next year international scientists joined the effort. To date, the team led by FAO and the U.S. Geological Survey has tracked more than 525 waterfowl from 24 species in 11 countries.

In the past 5 years, the involvement of wild birds has become clearer, Lei says. “The H5N1 strains from wild birds that subsequently arrived in Asia and Eastern Europe were most like the H5N1 strains of Qinghai Lake,” far from large poultry farms, he says. GPS data on migration paths are now being used for the first time to explore the relationships between different groups of birds and their interactions with domestic fowl, says Diann Prosser, a biologist at USGS’s Patuxent Wildlife Research Center in Beltsville, Maryland. This year, she says, researchers learned that the majority of bar-headed geese tagged at Qinghai spend their winters in the Lhasa region of Tibet, south of the lake. These wintering grounds have domestic poultry and captive bar-headed

goose farms—and H5N1 outbreaks have been reported there, suggesting a path for the virus to move from captive to wild birds.

Southeast of Lhasa, the ruddy shelduck may help explain the virus’s spread, says John Takekawa, an ecologist at USGS’s Western Ecological Research Center. In autumn and winter the ducks gather at Poyang Lake in the lower reaches of the Yangtze River within the East Asia Flyway (*Science*, 23 October 2009, p. 508). Qinghai strains can be traced to one early strain from Poyang based on the genomic analysis, Lei said. But recent work suggests that the viral reservoir may lie farther to the north, in Siberia—an area shared by both major Asian flyways—or that another as-yet-unstudied migratory bird may be carrying the virus from lake to lake. Since 2006, Xiao has led an international team to develop an early-warning system for H5N1 in Asia, focusing on agricultural and ecological risk factors.

Researchers need a better understanding of wild bird distribution, habitat use, and daily movements, Newman says. And the human



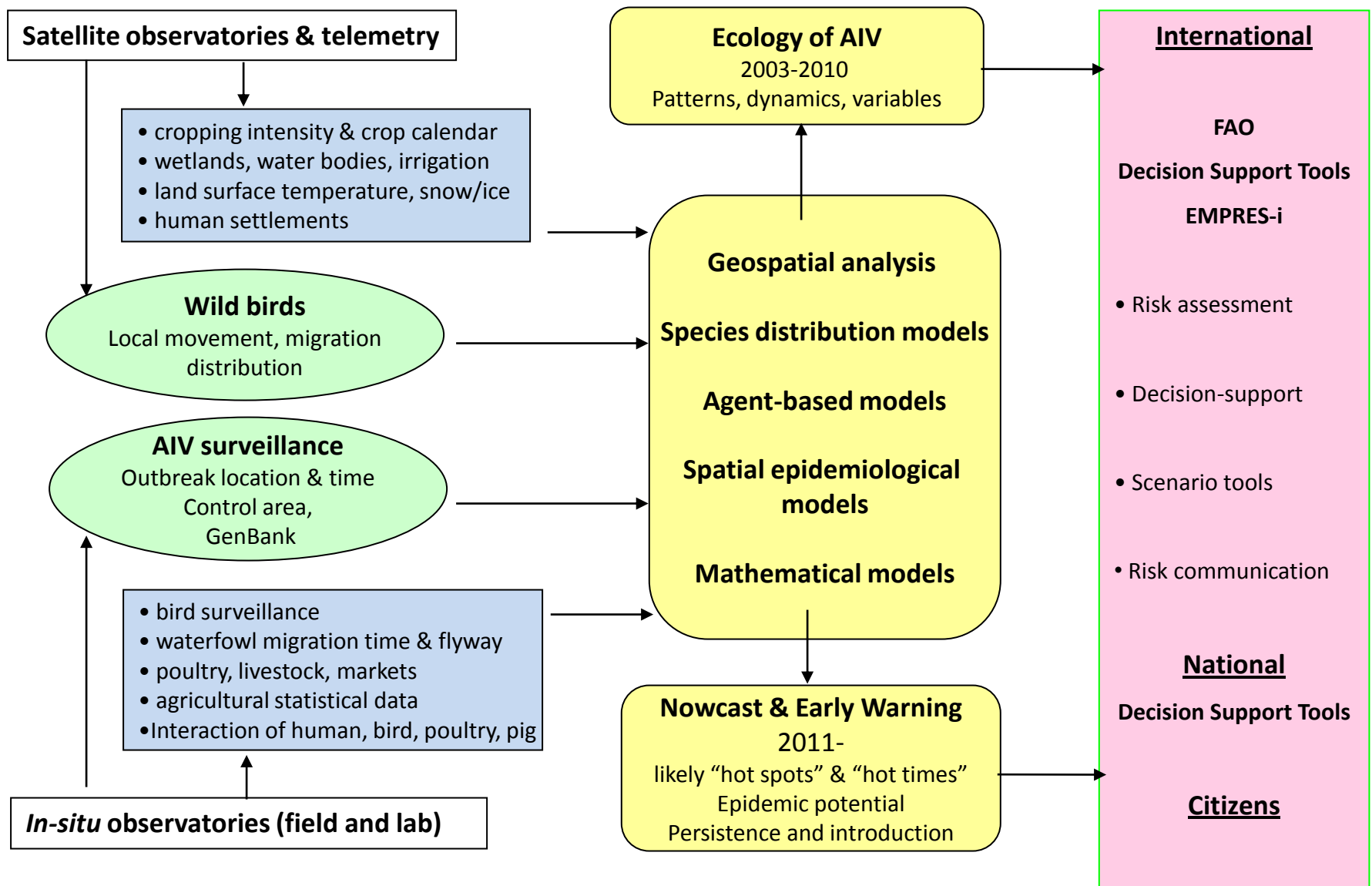
Mixing bowl. Scientists track birds entering and leaving Qinghai Lake with GPS transmitters.

role—including population growth and urbanization—must be better accounted for, says Takekawa. Why some people exposed to the virus become infected and others do not “is still an unsolved question,” says Shu Yuelong, director of the National Influenza Center of the Chinese Center for Disease Control and Prevention. China has launched a nationwide monitoring network to check poultry markets for H5N1. That’s a good start, but what’s needed is a global network, says Shu. It must get started now, he says, “without delay.”

—LI JIAO

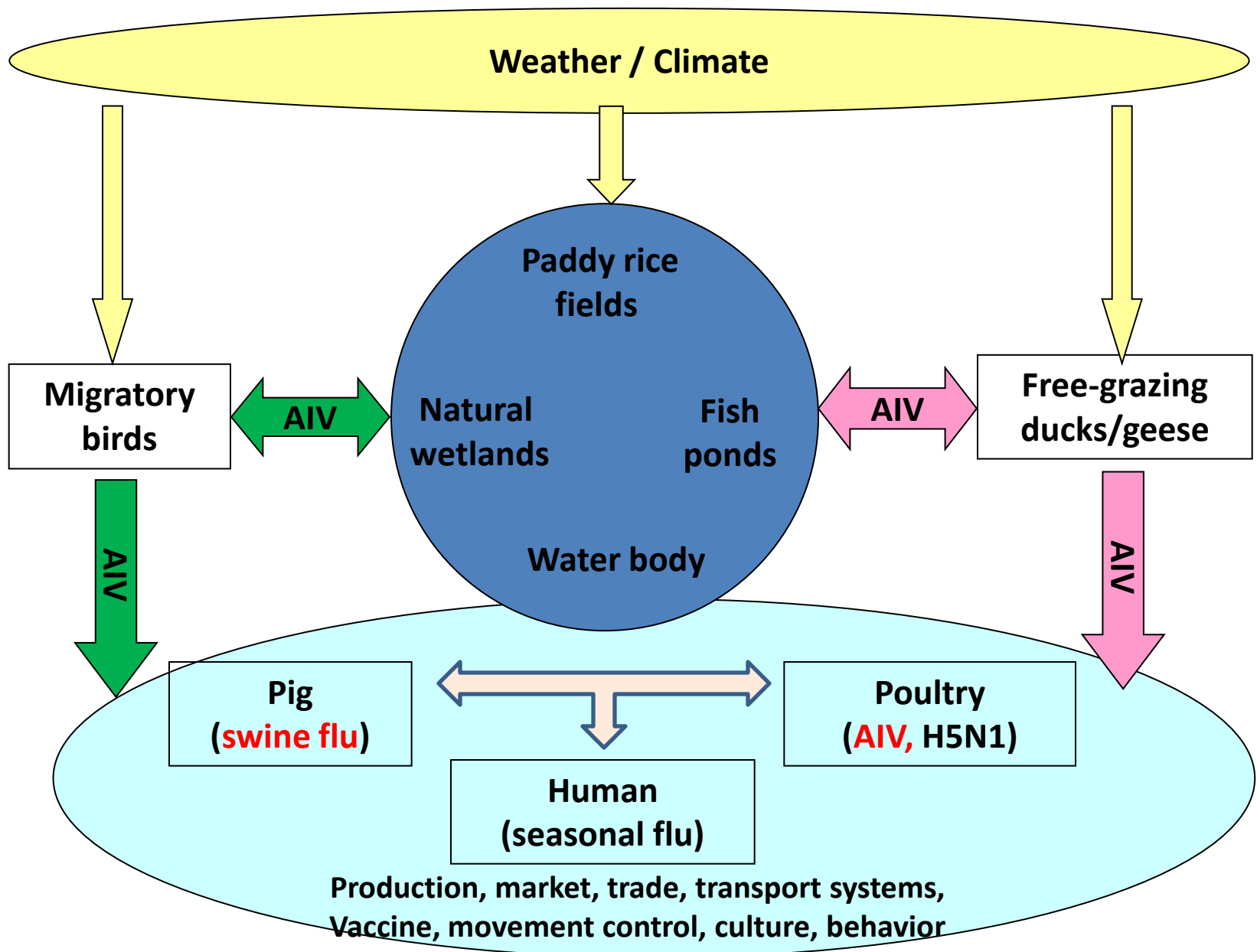
Li Jiao is a writer in Beijing.

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A schematic diagram for ecology, epidemiology and decision support systems of avian influenza

Are wild birds a victim or vector?



H5N1 outbreak in wild birds, Qinghai Lake, China

BREVIA

Highly Pathogenic H5N1 Influenza Virus Infection in Migratory Birds

J. Liu,^{1*} H. Xiao,^{2,4*} F. Lei,^{3*} Q. Zhu,⁵ K. Qin,¹ X.-w. Zhang,⁶
X.-l. Zhang,¹ D. Zhao,¹ G. Wang,^{2,4} Y. Feng,^{2,4} J. Ma,² W. Liu,²
J. Wang,⁶ G. F. Gao^{2,†}

Avian influenza virus (AIV) involving at least three subtypes, H5, H7, and H9, has emerged as an important pathogen in the poultry industry and is of major current global health concern (1). The first case report of chicken-to-human transmission was in Hong Kong in 1997 (2); since 2003, H5N1, a highly pathogenic AIV, has emerged in 10 Asian countries, including Thailand, Vietnam, and China (Fig. 1), and has claimed at least 53 human lives. Until recently, migratory waterfowl seemed to be exempt from widespread infection, although sporadic cases were recorded (3). Here we describe an outbreak of highly pathogenic H5N1 infection among waterfowl in Lake Qinghai, Gangcha County, Qinghai Province, in western China (Fig. 1).

On 4 May 2005, a few birds were found dead on Bird Island, and by the end of June more than a thousand birds were affected. This lake is one of the most important breeding locations for migratory birds that overwinter in Southeast Asia, Tibet, and India (Fig. 1). Several species were infected, including the bar-headed goose (*Anser indicus*), great black-headed gull (*Larus ichthyophaga*), and brown-headed gull (*Larus brunneicapillus*). Two key symptoms were noticed: abnormal neurological signs (tremor and opisthotonus) and diarrhea. Among the gross lesions, pancreatic necrosis was obvious and was confirmed by tissue section where extensive areas of lytic necrosis were seen, consistent with pathology observed in domestic geese and ducks infected with H5N1 AIV (3). Brain sections revealed glial cell infiltration, perivascular cuffing, and congestion in the blood vessels. Serological tests (4) from one bar-headed goose and one brown-headed gull confirmed the presence of higher-titer antibody against H5N1 AIV.

Several H5N1 viruses were isolated from the viscera, brain, and swabs of the oropharynx and cloaca of sick and dead birds. Four of the isolates from different bird species were com-

All eight infected chickens died within 20 hours, and seven of eight infected mice died within 72 hours; the last died 96 hours post-infection. Earlier isolates taken from ducks in China were less virulent in mice and chickens (6). Hence we speculate that viruses might be emerging from reassortants that originate in birds overwintering in southeast Asia (7).

The occurrence of highly pathogenic H5N1 AIV infection in migrant waterfowl indicates that this virus has the potential to be a global threat. Lake Qinghai is a breeding center for migrant birds that congregate from southeast Asia, Siberia, Australia, and New Zealand.

References and Notes

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2. K. Subbarao et al., *Science* 279, 393 (1998).
3. K. S. Li et al., *Nature* 430, 209 (2004).
4. Materials and methods are available as supporting material on Science Online.
5. M. Hatta et al., *Science* 293, 1840 (2001).
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8. Available at www.china.com.cn/chinese/zhuanti/qh/483177.htm
9. Supported by the Ministry of Science and Technology, P.R. China [grant nos. 2004BA519A29, 2004BA519A11, 2004BA519A10, and 2004BA519A50]; National Basic Research Program (973) of China 2005CB523000; the Chinese Academy of Sciences (The President Fund and CAS Information Special grant no. INF105-508-3-A2), the State Forestry Administration of China, and the National Natural Sciences Foundation of China (grant nos. 30471282 and 30228025). Sequence data derived from this study were deposited in GenBank with accession no. DQ100542-DQ100573.

Supporting Online Material
www.sciencemag.org/cgi/content/full/1115273/DC1
Materials and Methods
Figs. S1 and S2
References and Notes

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E-mail: gaof@im.ac.cn (G.F.G.); jhl@cau.edu.cn (J.L.)

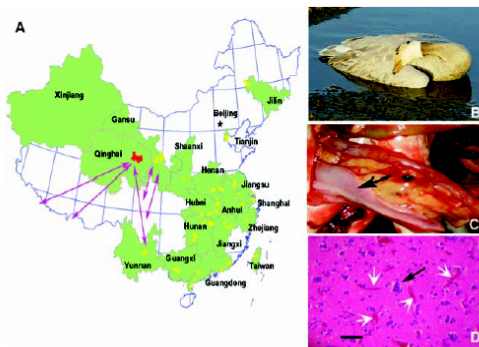
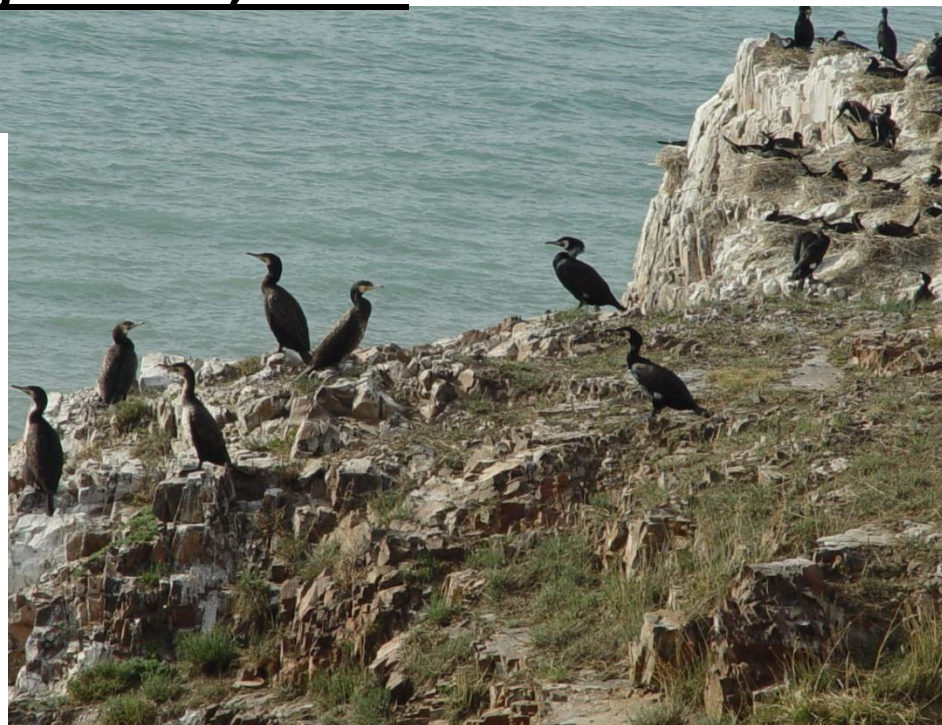


Fig. 1. (A) The reported H5N1 AIV prevalence sites during the 2004 outbreak in China are highlighted in yellow (8). Arrows indicate the migratory routes of the bar-headed goose (A. indicus) to Lake Qinghai. (B) A sick bar-headed goose showing typical opisthotonus before dying. (C) Bar-headed goose pancreas with pin-point necrotic lesions (arrow). (D) Microscopic lesions in bar-headed goose brain, showing congestion in the blood vessels (white arrows) and glial cell infiltration (black arrow). Hematoxylin and eosin $\times 25$ (scale bar, 50 μ m).

pletely sequenced (4) and appeared to be closely related. None of the GenBank sequence data for known H5N1 AIV genomes completely matched our sequences, implying the viruses are reassortants. Five of the eight genomic segments (M, PA, PB1, PB2, and NS) were closely related to a Hong Kong 2004 isolate (A/peruquine falcon/HK/D0028/04) (3). We observed several characteristics in our four isolates: first, the sequence PQGERRRKKR/G, denoting multiple basic amino acids at the cleavage site of the hemagglutinin; second, a virulence island in the PB2 gene, E627K, first seen in Hong Kong in 1997 (5); and third, a deletion of 20 amino acids in neuraminidase (amino acid positions 49 to 69), also associated with high virulence.

To test virulence, mice and chickens were infected with the BbGoose/QH/1/05 (4) isolate.



Transmitters



Satellite telemetry of waterfowl

Capture and mark waterfowl to study their local movement, habitat use, and migration in relation to potential HAPI H5N1 spread

Qinghai Lake, China

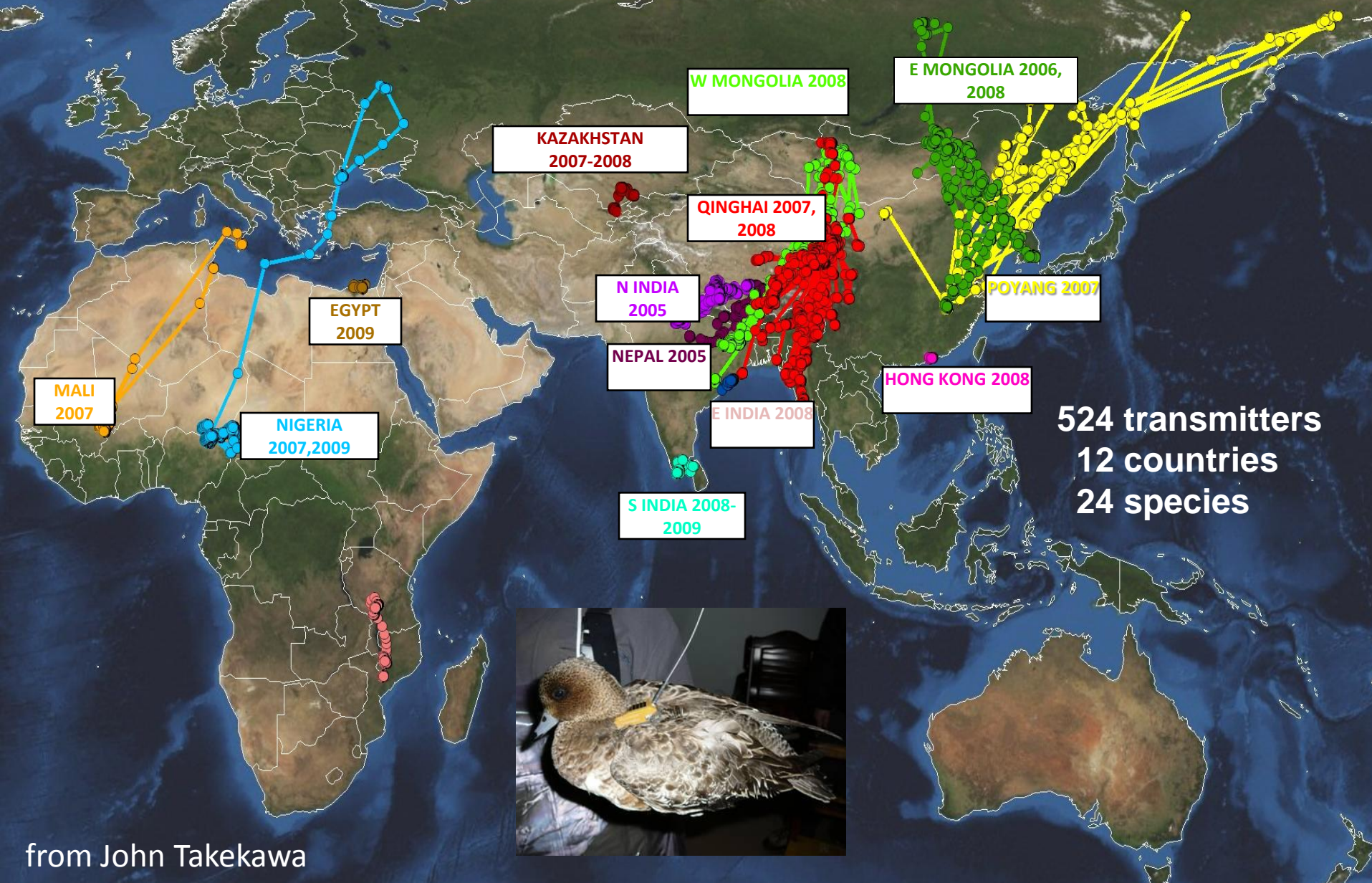
Ruddy shelduck (*Tadorna ferruginea*)

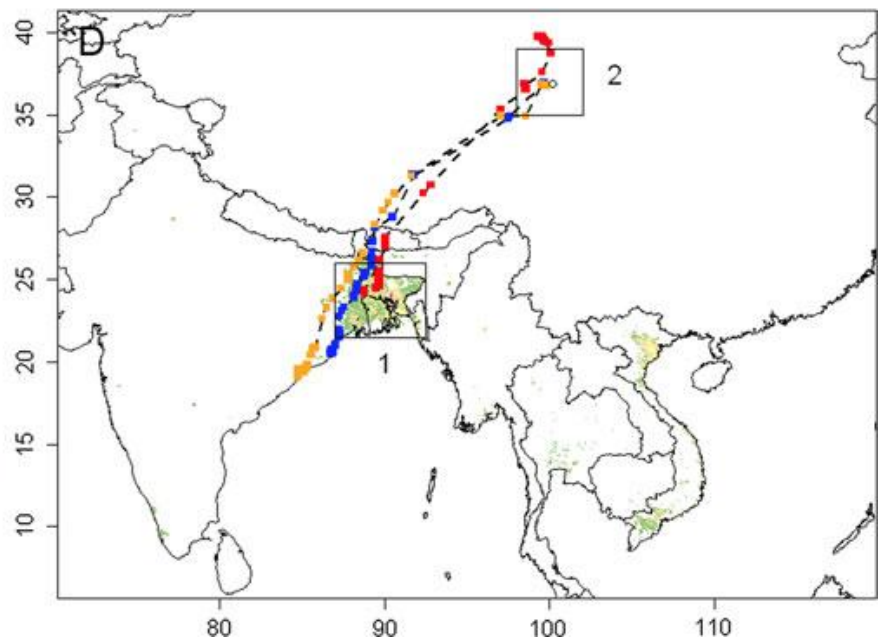
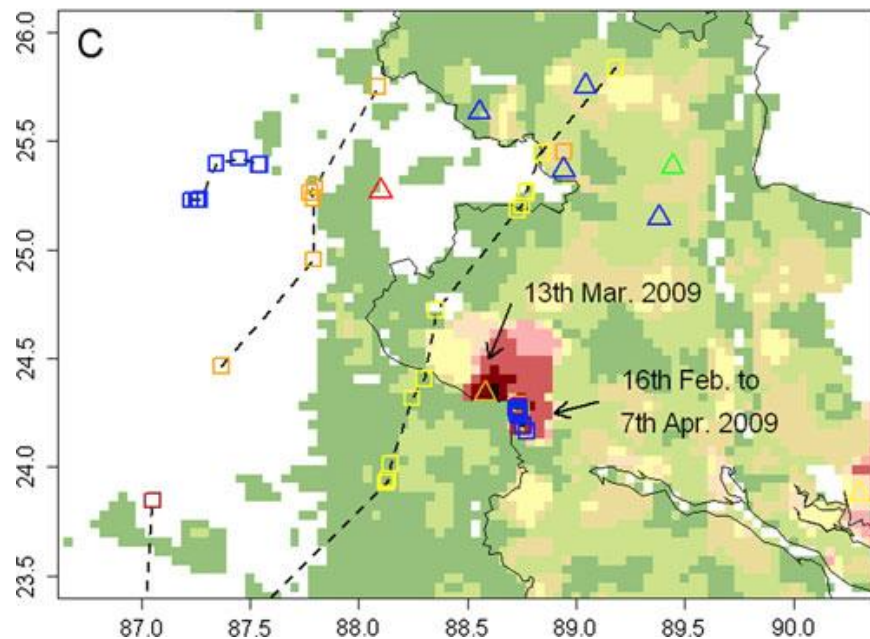
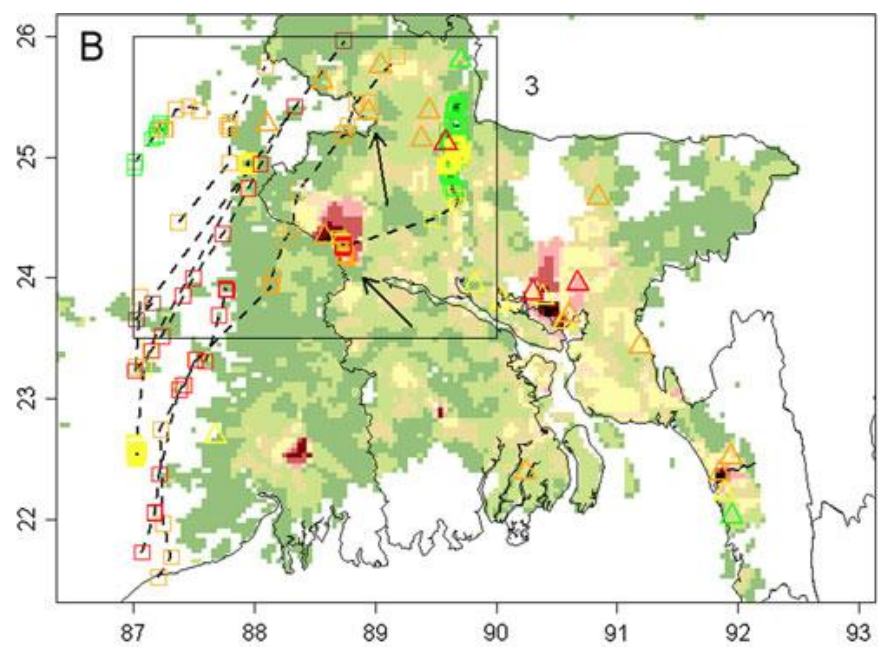
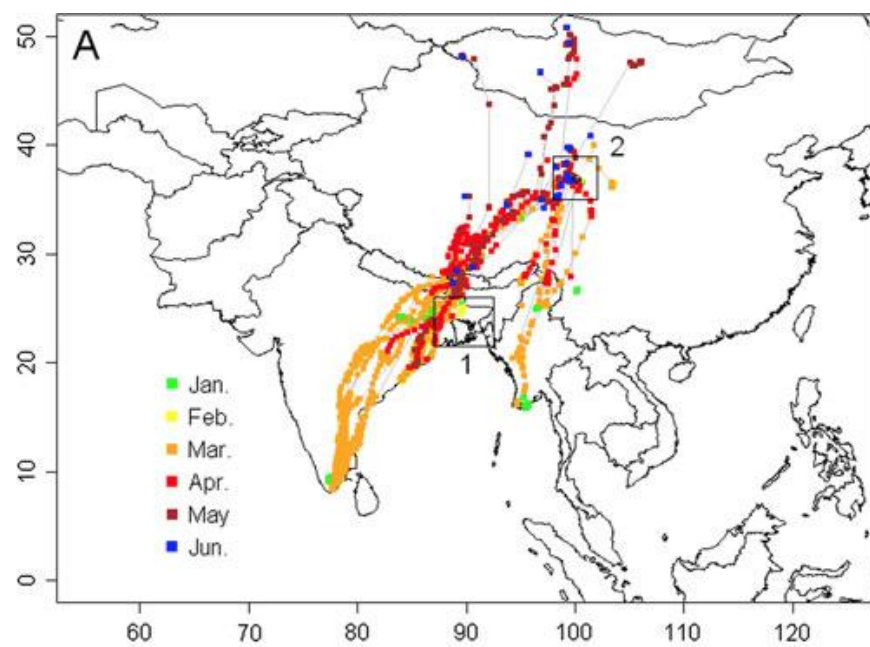


Bar-headed geese (*Anser indicus*)



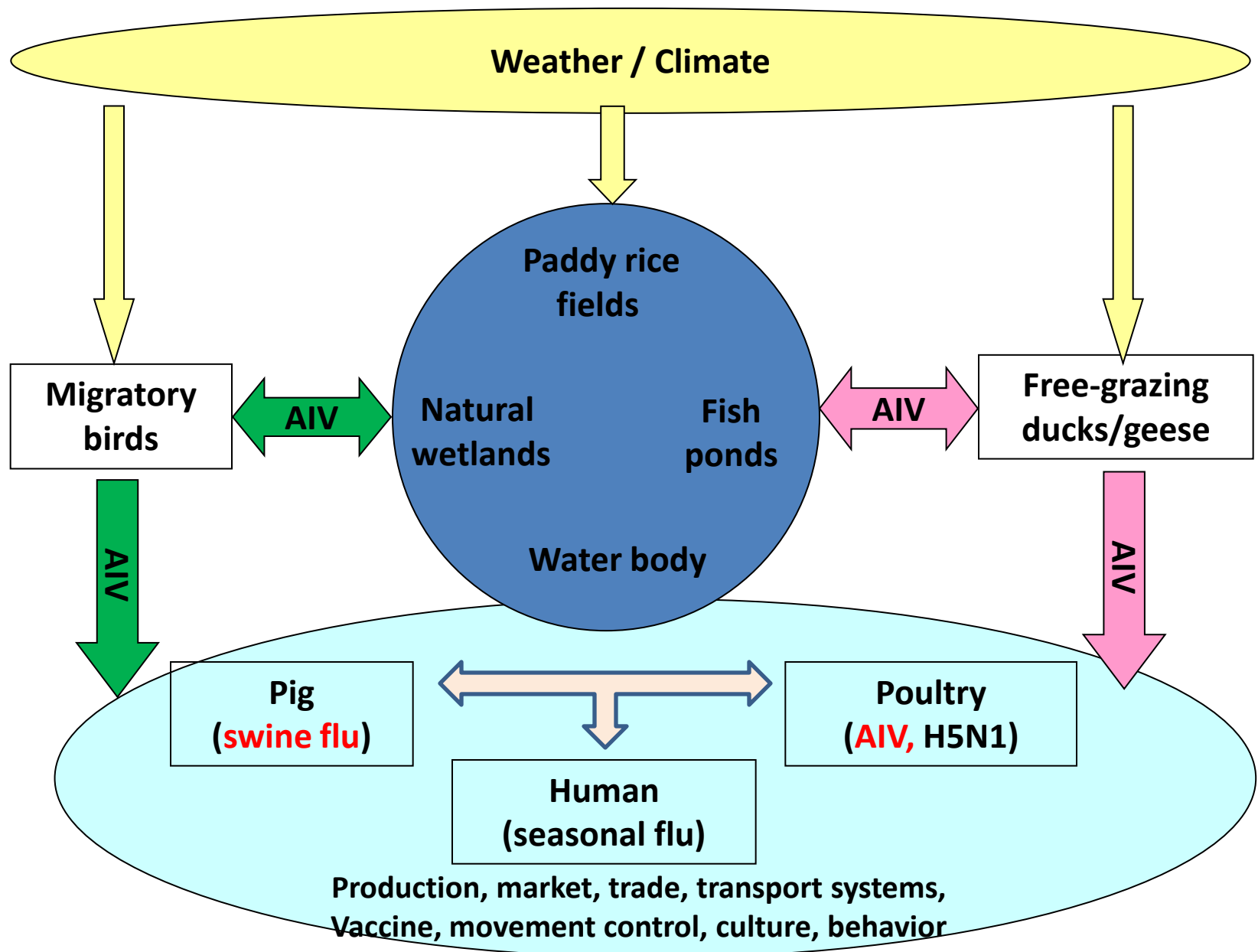
Track migratory waterbirds through GPS-based satellite telemetry





Gilbert et al., 2011, Flying over an infected landscape: distribution of HPAI H5N1 risk in South Asia and satellite tracking of wild waterfowl, Ecohealth,

How to reduce spatial uncertainty in complex systems?



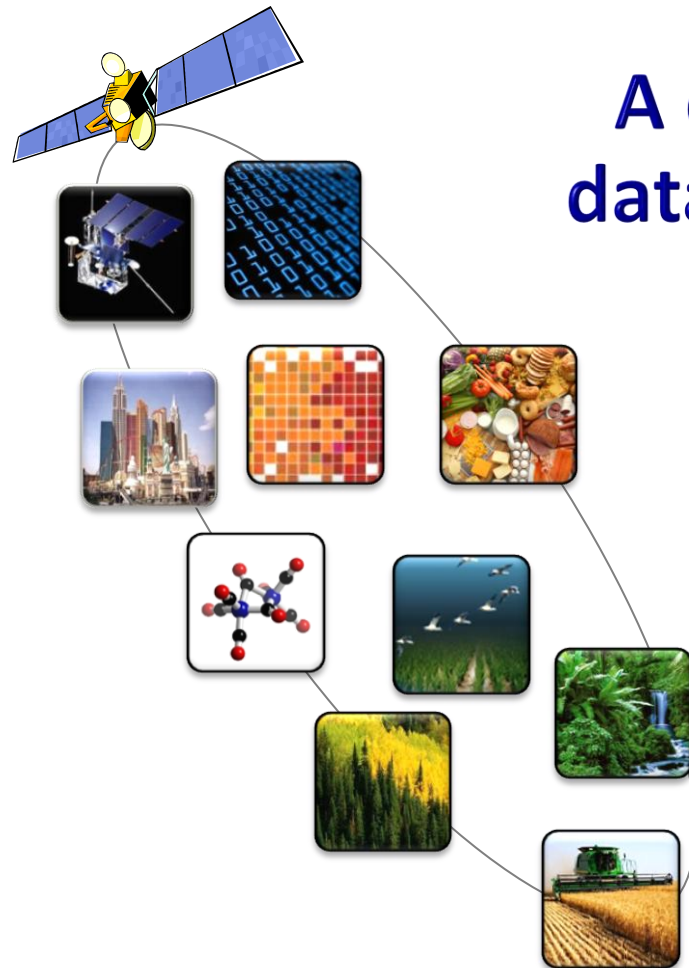
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Geo-tagged field photos are ground reference data, and can be used for disease surveillance & epidemiology: poultry farms, free grazing, markets, virus samples

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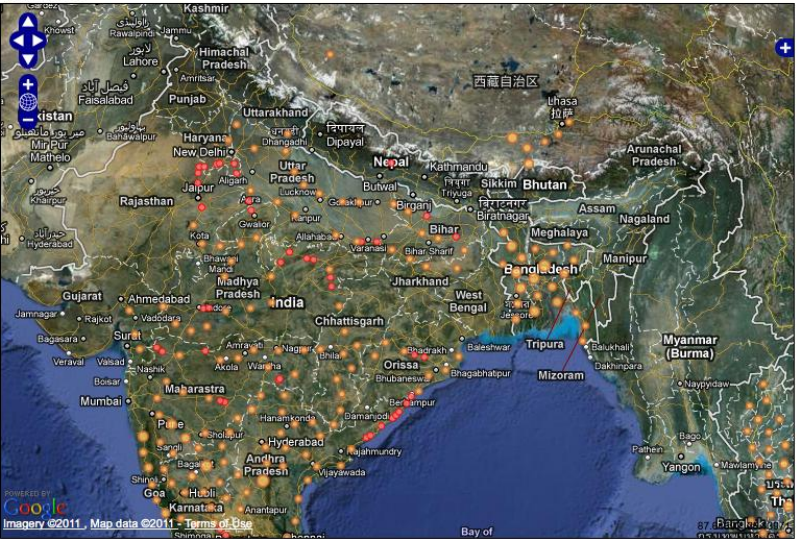
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358.2m altitude.

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Description: paddy rice, harvested, free grazing ducks
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Link geo-tagged field photos with satellite time series images


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97.5862 °W, 36.1904 °N
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CSV file and images.

Original images.

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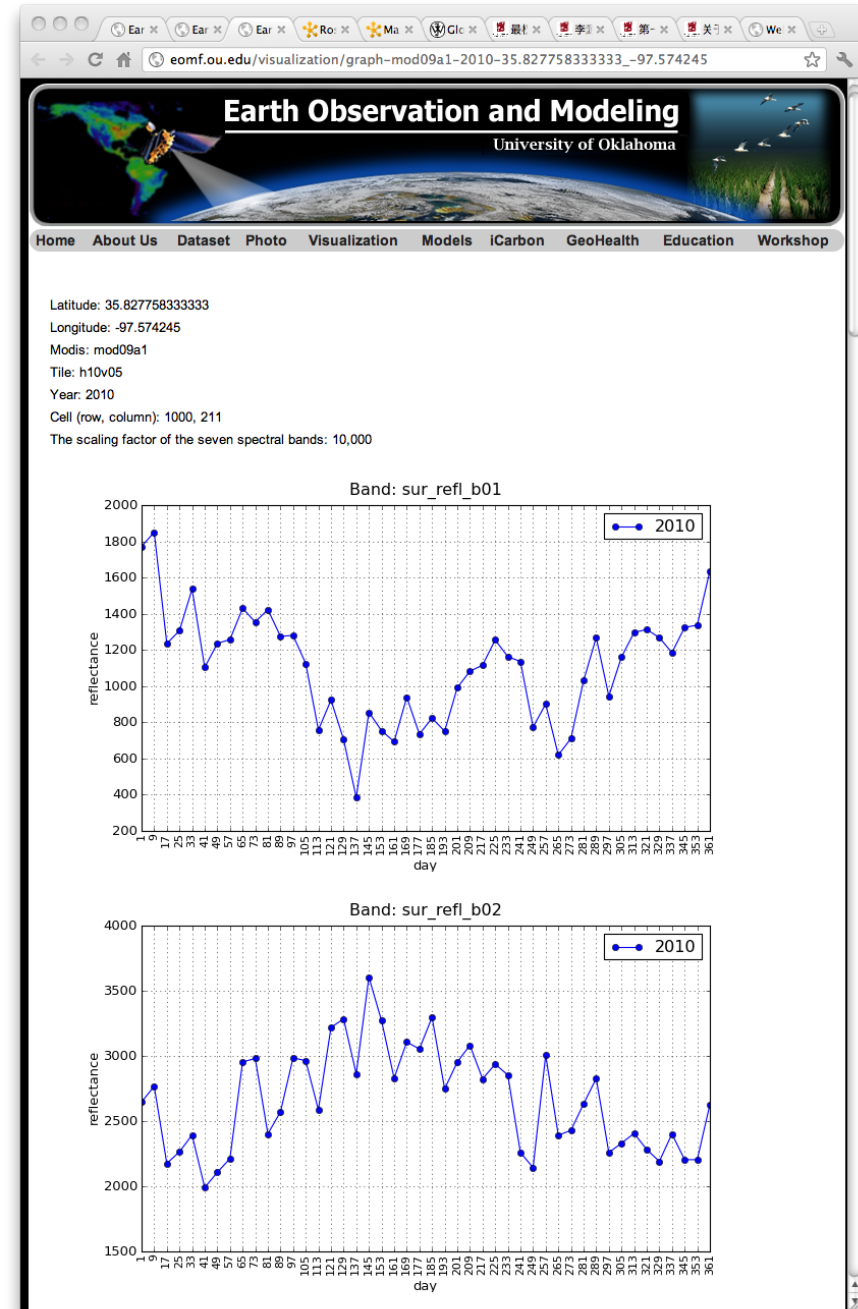
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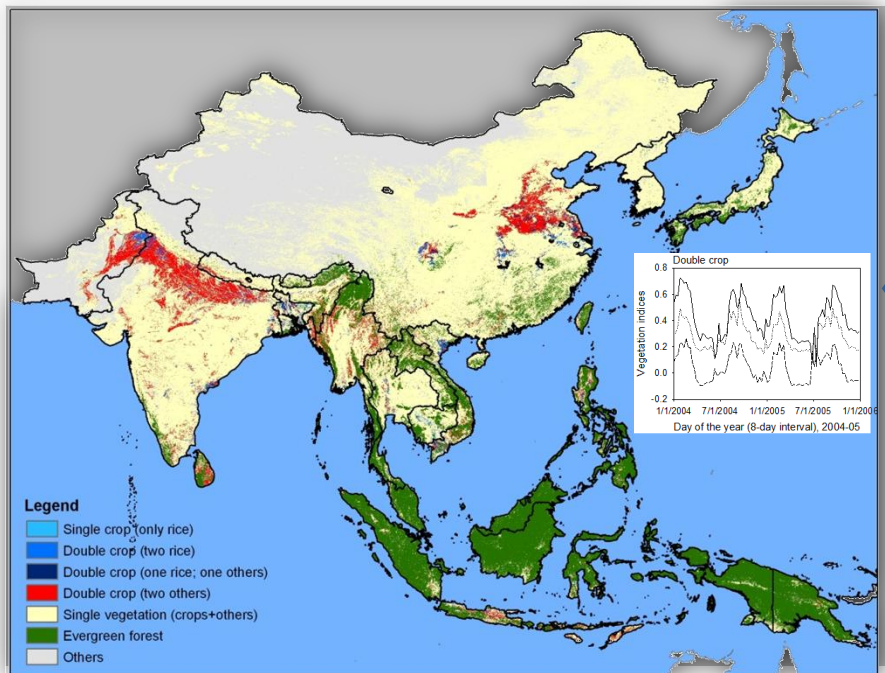
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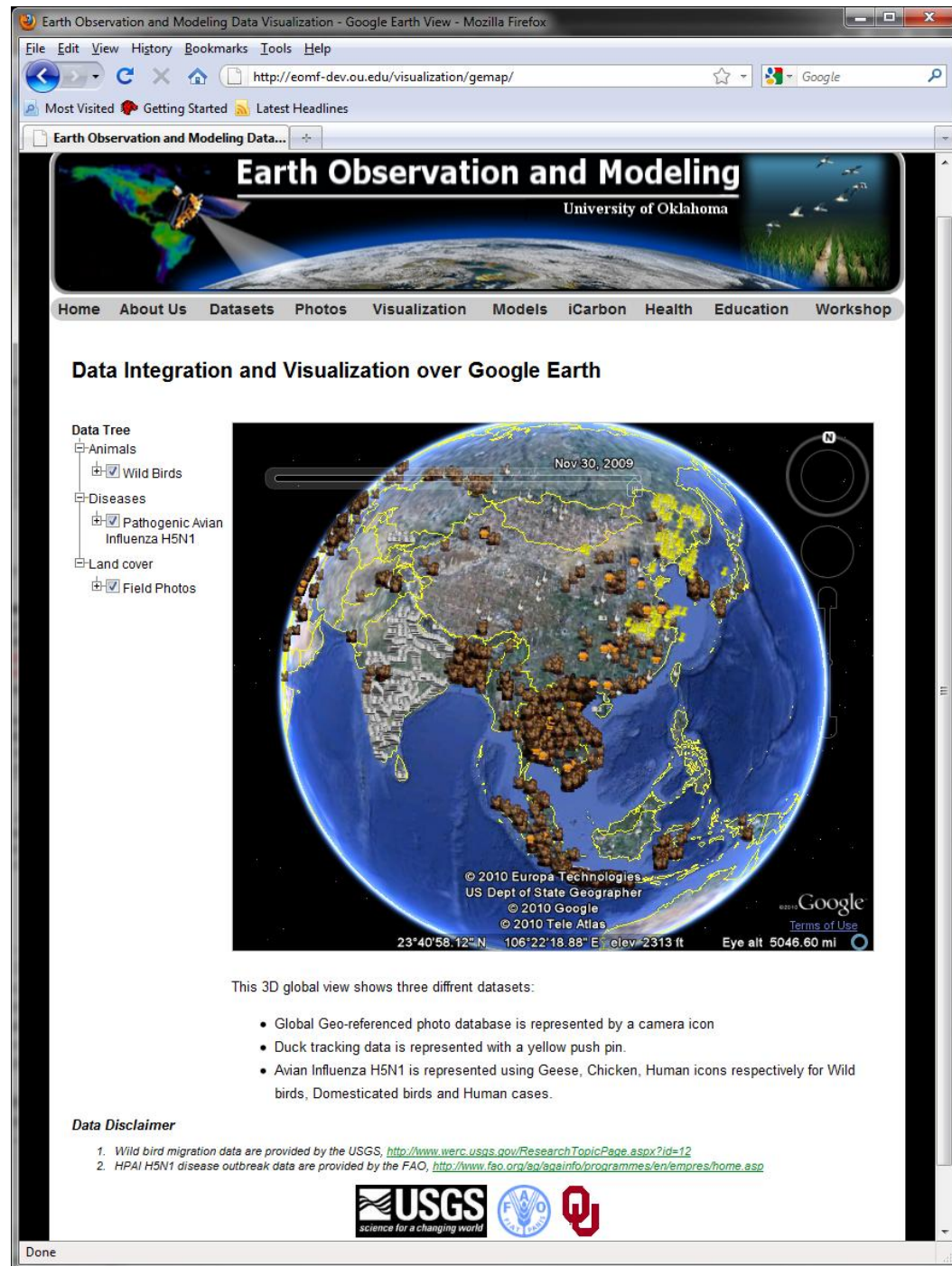
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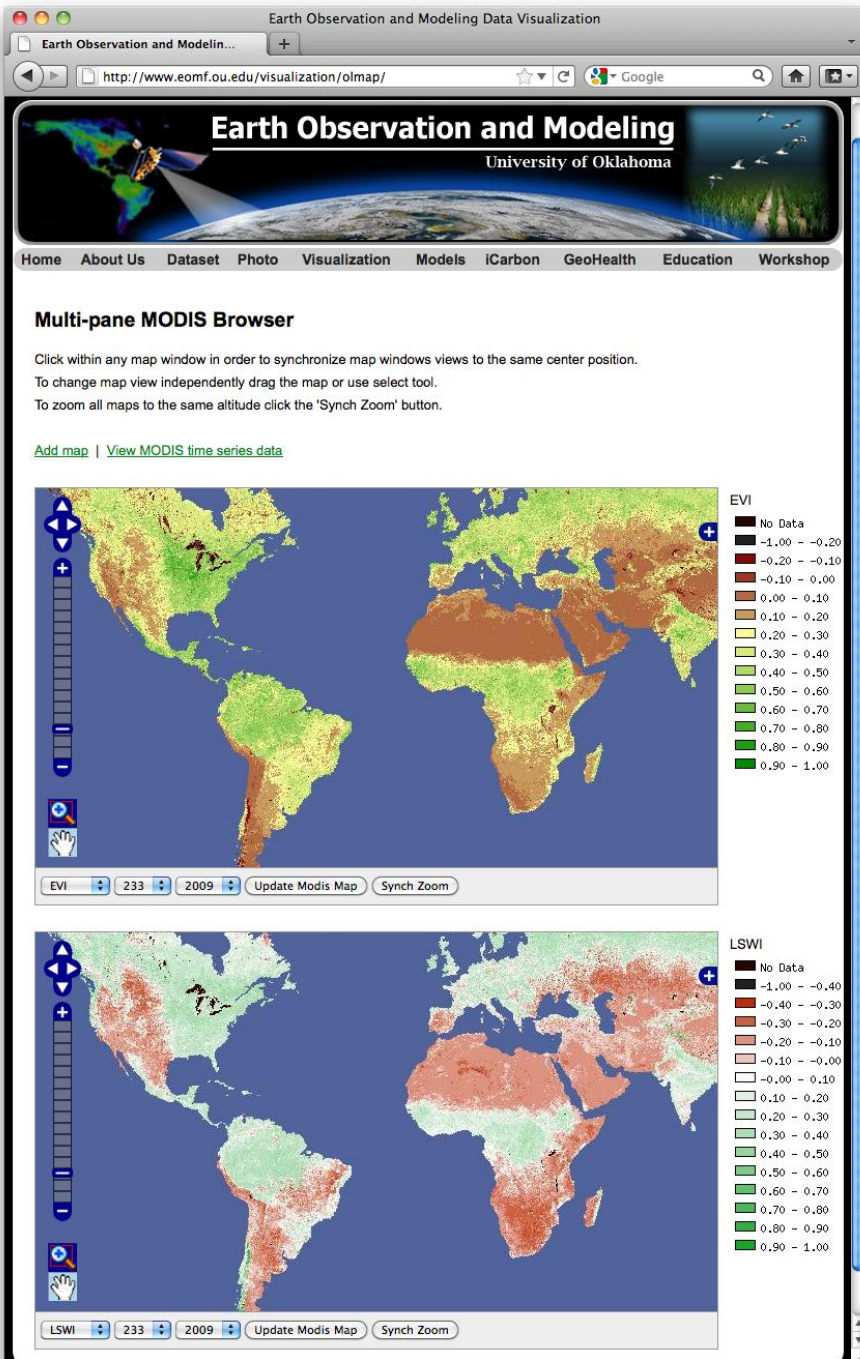
GeoHealth data portal

- Informatics approaches to integrate disparate sources of datasets
- Data mining and visualization

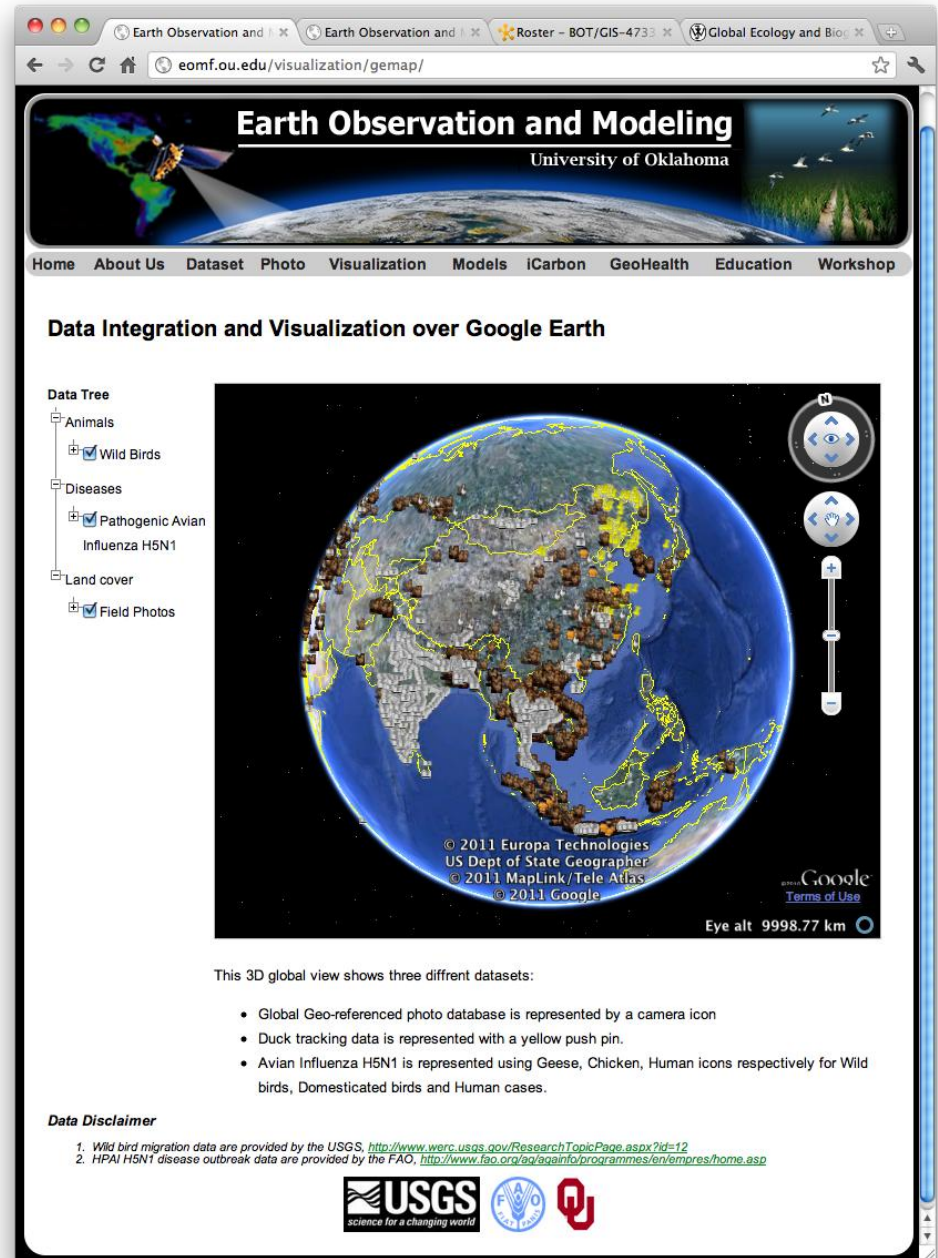
Disparate datasets

- Highly pathogenic avian influenza H5N1 data
- Human population
- Poultry, pigs,
- Satellite telemetry of wild birds
 - Wild bird migration
- Satellite-based mapping of agricultural land use - paddy rice
- AIV surveillance data (GenBank, OpenFlu)
- Market chain data
- Geo-tagged field photos
- Weather and climate





Data visualization and integration



Food and Agriculture Organization of the United Nations (FAO)

Animal Production and Health Division

Decision support system in FAO

The Emergency Prevention System (EMPRES) for Priority Animal and Plant Pest and Diseases

Crisis Management Center


www.fao.org/avianflu/en/index.html

AVIAN INFLUENZA Agriculture Department
Animal Production and Health Division

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BIRD FLU REARS ITS HEAD AGAIN



Preparedness and surveillance remain essential. This is no time for complacency. No one can let their guard down with avian influenza...>>>

NEWSLETTERS & BROCHURES

- FAO AIDNews: **Latest issue!!!** [archive...]
- ECTAD News Asia and the Pacific **Latest issue!!!** [archive...]
- The Avian Influenza Project in the Great Lakes [En - Fr] [click [here](#) for archive]

Q & A

- How is avian influenza transmitted?
- Can wild birds transmit avian influenza to humans?
- What can be done to limit spread of the disease?

[click [here](#) for FAO's answers to these and other questions]

NEWS

27 July 2011
The science against avian influenza in Viet Nam is sponsored by donors >>>

22 July 2011
Ten lessons learned from the work of UNSIC >>> [click [here](#) for archive]

KEY DOCUMENTS

The Global Strategy for the Prevention and Control of H5N1 Highly Pathogenic Avian Influenza (October 2008) >>>

Global Programme for the Prevention and Control of H5N1 Highly Pathogenic Avian Influenza (February 2008) >>>

Fourth Report of the Global Programme for the Prevention and Control of Highly Pathogenic Avian Influenza (January - December 2010) >>>

FAO Regional Strategy for Highly Pathogenic Avian Influenza and other Emerging Diseases of Animals in Asia and the Pacific >>>


Second Real-Time evaluation of FAO's work on Highly Pathogenic Avian Influenza (RTE2 - zip) >>>

Management response to RTE2 >>>

Understanding avian influenza - A major new and wide-ranging overview from FAO >>>

Approaches to controlling, preventing and eliminating H5N1 HPAI in endemic countries >>> [click [here](#) for more documents]

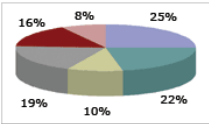
OUTBREAKS



H5N1 HPAI GLOBAL OVERVIEW

Issue No.28 April-June 2011 [click [here](#) for archive]

DONOR SUPPORT



FUNDING REQUEST

Emerging and Transboundary Animal Diseases Funding Request to Donors >>>

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he-09-03b.pdf Members_updated_Au....snp 960912.pdf Show All

Global Early Warning System (GLEWS) for animal diseases that are transmissible to humans

FAO, OIE and WHO established it in 7/2006.

The screenshot displays the GLEWS website in a web browser. The header features the GLEWS logo and the text "Global Early Warning System for Major Animal Diseases, including Zoonoses", along with logos for FAO, OIE, and WHO. A search bar is located on the right. The main content area is divided into two columns. The left column, titled "Latest Diseases Events", lists recent disease outbreaks with dates and locations, such as "18/08/2011 Confirmed Highly Pathogenic Avian Influenza in India" and "26/05/2011 Confirmed Foot and Mouth Disease in Kazakhstan". The right column, titled "Diseases Events Map", shows a world map with red pins indicating disease locations. Below the map are tabs for "Map", "Satellite", "Hybrid", and "Terrain". A sidebar on the left contains navigation links like "Home", "About GLEWS", "Objectives", "Project background", "Structure and governance", "Disease priority list", "Publications", "Related links", and "In the Spotlight". The main content area below the map features a section titled "EMPRES Bulletin No. 38" dated 28 June 2011, with a link to a PDF. Below this is a news article titled "The world is free from rinderpest: OIE completed global free status recognition" dated 03 June 2011, which discusses the recognition of 198 countries as free of rinderpest. Another article titled "Fourth Report of the Global Programme for the Prevention and Control of Highly Pathogenic Avian Influenza (HPAI)" dated 01 June 2011 is also visible. A right sidebar contains a quote about the GLEWS system and a section titled "INFORMATION SYSTEMS" with a link to "FAO EMPRES-i Global Animal Disease Information System". The browser's address bar shows "www.glews.net". The bottom of the browser window displays several open files: "he-09-03b.pdf", "Members_updated_Au....snp", and "960912.pdf", along with a "Show All" button.

To link FAO EMPRES-i data portal with OU EOMF GeoHealth data portal

empres-i.fao.org/empres-i/home

EMPRES-i Global animal disease information system

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Food and Agriculture Organization of the United Nations

EMPRES-i
Global Animal Disease Information System

Home Disease Events Library Directory About Empres-i Sign-in

EMPRES-i website is a global animal health information system of FAO's Emergency Prevention Programme for Transboundary Animal Diseases (EMPRES), that focus on the user need to easily find and collect in one place all the information available for animal health and transboundary animal diseases (TADs). EMPRES-i compiles, stores and verifies animal diseases outbreaks data (including zoonoses) from numerous sources (FAO representatives, FAO reports, OIE reports, official government, European Commission, FAO reference centres, laboratories,...), for early warning and risk analysis. [More Info](#)

Disease events list RSS

08/09/2011: Highly pathogenic avian influenza in Assam (India)
06/09/2011: Highly pathogenic avian influenza in Dhaka (Bangladesh)
02/09/2011: Highly pathogenic avian influenza in Thai Binh (Viet Nam)
31/08/2011: Highly pathogenic avian influenza in Quang Ngai (Viet Nam)
30/08/2011: Highly pathogenic avian influenza in Quang Tri (Viet Nam)
30/08/2011: Highly pathogenic avian influenza in Quang Tri (Viet Nam)
29/08/2011: Highly pathogenic avian influenza in Khulna (Bangladesh)
27/08/2011: Highly pathogenic avian influenza in Khulna (Bangladesh)
26/08/2011: Highly pathogenic avian influenza in Khulna (Bangladesh)

Disease events map

All Regions/All Countries-territories - Highly pathogenic avian influenza [since 01/03/2011]

Disease events chart

By month By region

Total number of Highly pathogenic avian influenza since 01/03/2011

March April May June July August

Confirmed Deceased

Library

All Books Guidelines Bulletins

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2011 Avian Influenza Disease Emergency: Issue No. 80 (07/09/2011)
Sigfrido Burgos, ECTAD Communications Unit (8pp)
[\[MORE\]](#) [\[PDF\]](#)

2011 EMPRES - Boletín de enfermedades transfronterizas de los animales: Fascículo No. 37 null (52pp)
[\[MORE\]](#) [\[PDF\]](#)

2011 Wild bird highly pathogenic avian influenza surveillance (Thai language)
Kamie Rose, Scott Newman, Marcela Uhart, Juan Lubroth (66pp)
[\[MORE\]](#) [\[PDF\]](#)

Directory

EMPRES-i compiles information from numerous sources (FAO representatives or country missions, FAO reports, OIE, official government sources, European Commission, FAO reference centres, laboratories and FAO collaborators) and produces composite maps in a representative effort to provide full and accurate information.

EMPRES-i welcomes information on animal disease events/rumours worldwide. This information will be tracked by FAO for further validation and verification through the network of FAO officers deployed in the field in 192 member countries, FAO collaborators and personal contacts with NGOs, and other institutions.

EMPRES-i team also welcomes information to clarify/rectify disease events reported on the website. If you want to share any such information with us please send a message to empres-i@fao.org. If you have any questions or suggestions on how to improve the EMPRES-i platform and the information provided please send your message to empres-i@fao.org

If you want to be informed about news concerning

Comments: EMPRES-i EMPRES-i Information System © FAO, 2011 EMPRES-i Ver: 1.5

Earth Observation and Modeling Data Visualization - Google Earth View - Mozilla Firefox

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http://eomf-dev.ou.edu/visualization/gemap/

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Data Integration and Visualization over Google Earth

Data Tree

- Animals
 - Wild Birds
- Diseases
 - Pathogenic Avian Influenza H5N1
- Land cover
 - Field Photos

Nov 30, 2009

© 2010 Europa Technologies
US Dept of State Geographer
© 2010 Google
© 2010 Tele Atlas

23°40'58.12"N 106°22'18.88"E elev 2313 ft Eye alt 5046.60 mi

This 3D global view shows three different datasets:

- Global Geo-referenced photo database is represented by a camera icon
- Duck tracking data is represented with a yellow push pin.
- Avian Influenza H5N1 is represented using Geese, Chicken, Human icons respectively for Wild birds, Domesticated birds and Human cases.

Data Disclaimer

- Wild bird migration data are provided by the USGS, <http://www.werc.usgs.gov/ResearchTopicPage.aspx?id=12>
- HPAI H5N1 disease outbreak data are provided by the FAO, <http://www.fao.org/ag/qa/info/programmes/en/empres/home.asp>

USGS science for a changing world

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